

Healthy Efficient New Gas Homes Study (HENGH)



*Rengie
Chan*



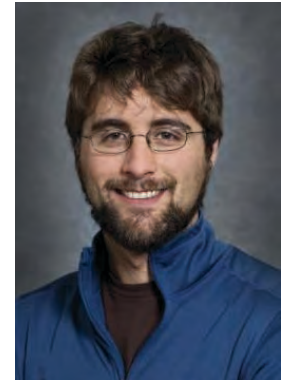
*Yang-
Seon
Kim*



*Brett
Singer*



*Iain
Walker*



*Brennan
Less*

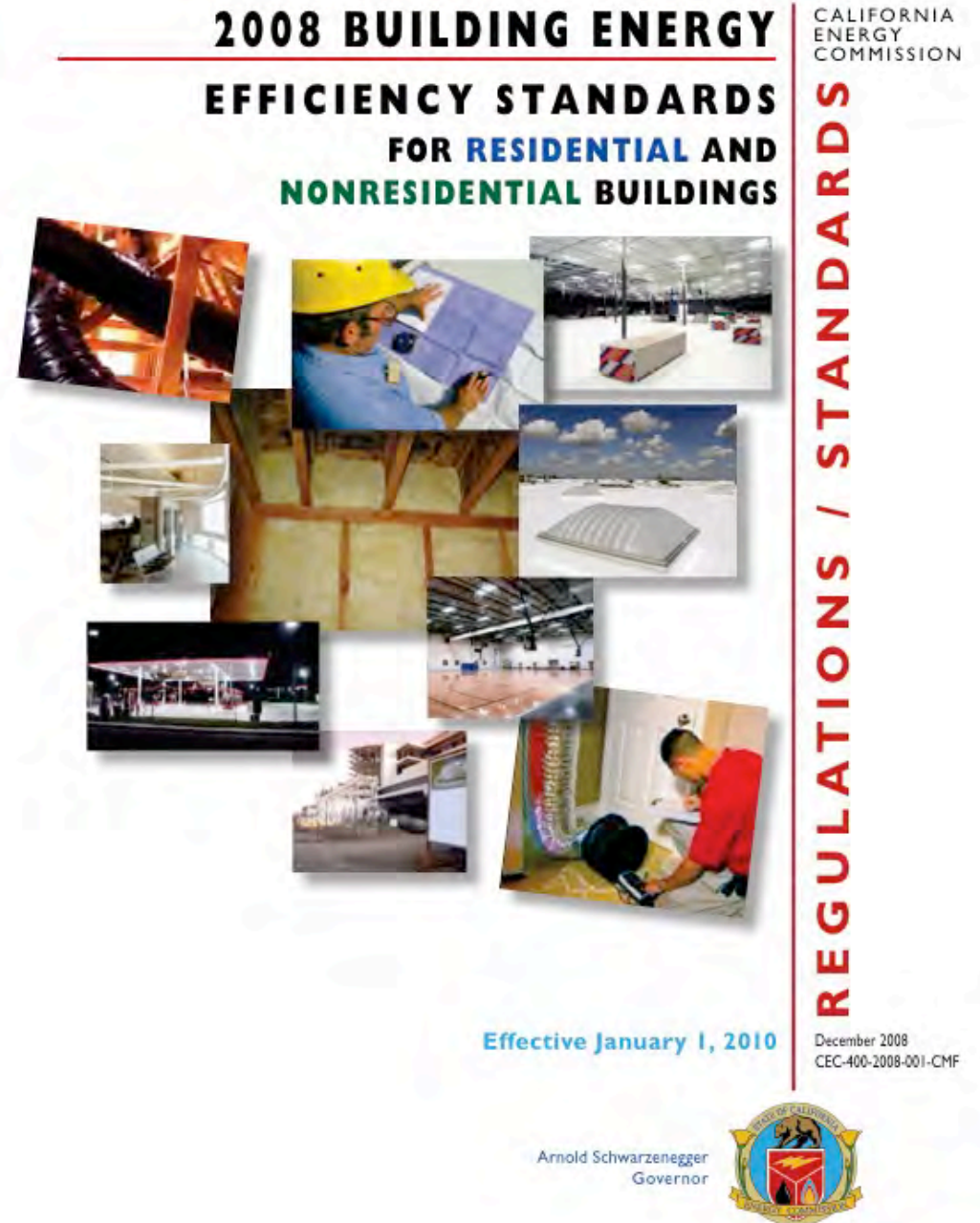


In 2008, mechanical ventilation requirements were added to California Title 24 to address adverse impacts that could potentially result from air sealing envelopes to reduce infiltration and improve energy efficiency.

Are these requirements working?

Are other changes necessary?

E.g., airtightness limits, filtration



HENGH has three parts:

1. Survey of California homes
2. Simulations for energy, ventilation and airtightness
3. Field study of IAQ in California Homes

Key Survey Results (2648 responses)

- Field study homes are representative of new homes for house size and occupancy (1000 sq.ft. per person)
- 90% of occupants rated IAQ neutral or better and were generally more satisfied with IAQ than outdoor air quality
- Range hoods that were vented to outside were used more often than recirculating hoods
- Increased bathroom exhaust venting and fewer occupants reduces complaints of mustiness/odor
- Households with sensitive occupants were much more likely to use air cleaning devices
- Homes with mechanical ventilation systems have higher IAQ satisfaction.

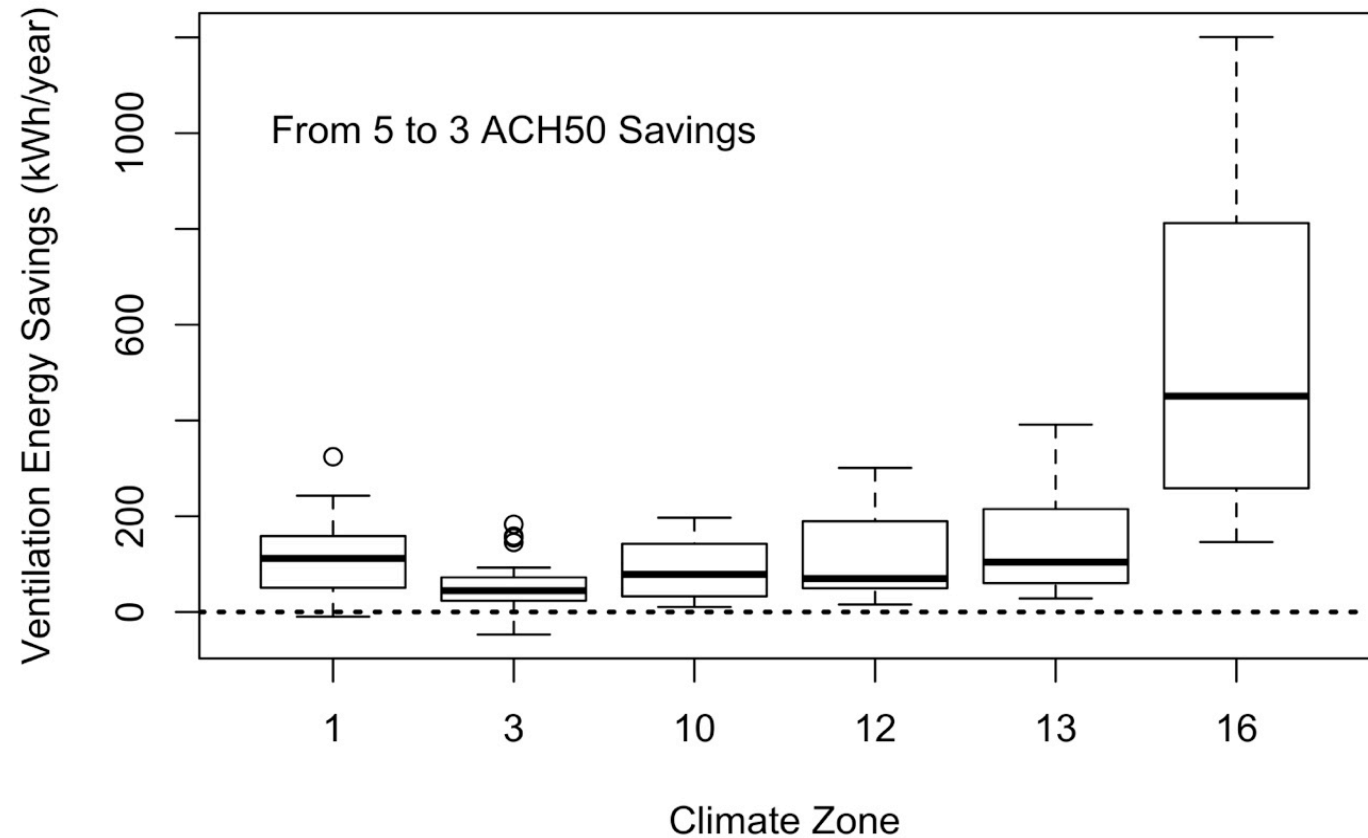
Simulation Summary

REGCAP House and HVAC simulation model

Prototype Home	1-story, 2,100 ft ²					2-story, 2,700 ft ²			
CEC Climate Zone	1 (Arcata)	3 (Oakland)		10 (Riverside)		12 (Sacramento)		13 (Fresno)	16 (Blue Canyon)
Envelope Airtightness (ACH ₅₀)	0.6		1		2		3		5
Whole house fan Sizing Method	None	T24 2008	T24 2013 Target	T-24 2013 Inf	ASHRAE 62.2- 2016	T24 2019	T24 2019phi		Builder Practice
Fan Type	Exhaust					Balanced			

Key Simulation Results

- 3 ACH50 airtightness would result in statewide HVAC energy savings of about 3% (typically less than 100 kWh)
 - 2019 requirements lead to more uniform air flow with house leakage
 - CA climates are mild

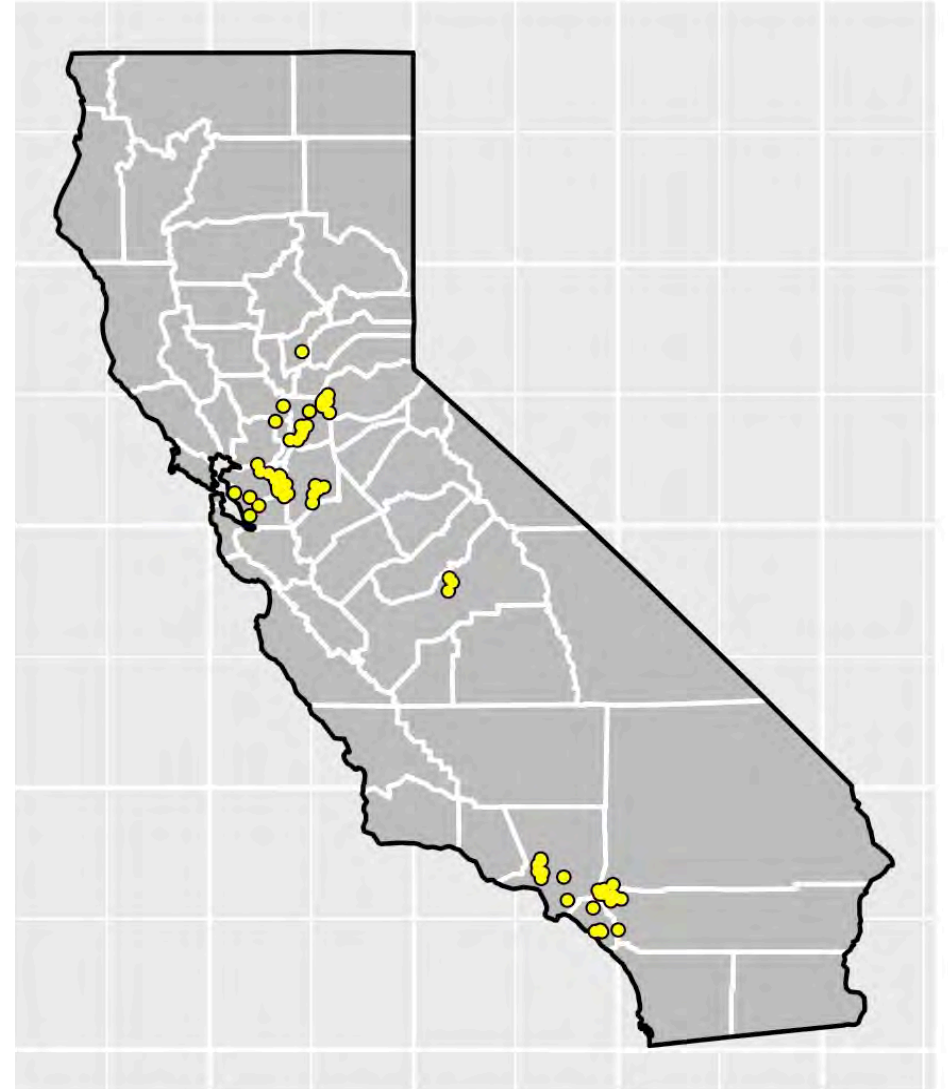


Key Simulation Results

- Impact of new 2019 ventilation requirements c/w current standard:
 - 45% reduction in contaminant concentrations
 - 7% increase in HVAC energy use
- *However*, field survey showed that installed fans are much larger capacity than minimum requirements so these impacts are likely to be much smaller in magnitude.
- Little change in builder practice required to meet the new standard
- Consider improving combination of infiltration and mechanical ventilation to reduce home-to-home variability
 - Use superposition from ASHRAE 62.2-2016 or LBNL exponential approach

Field Study of 70 New Homes

- All homes have natural gas appliances
- All homes have mechanical ventilation
 - Whole house ventilation [ON]
 - Bathroom exhaust fan
 - Kitchen range hood exhaust to outside
- Indoor air quality, occupant activities and ventilation use monitored for one week in each home



IAQ Monitoring

PM2.5



CO₂
T,
RH



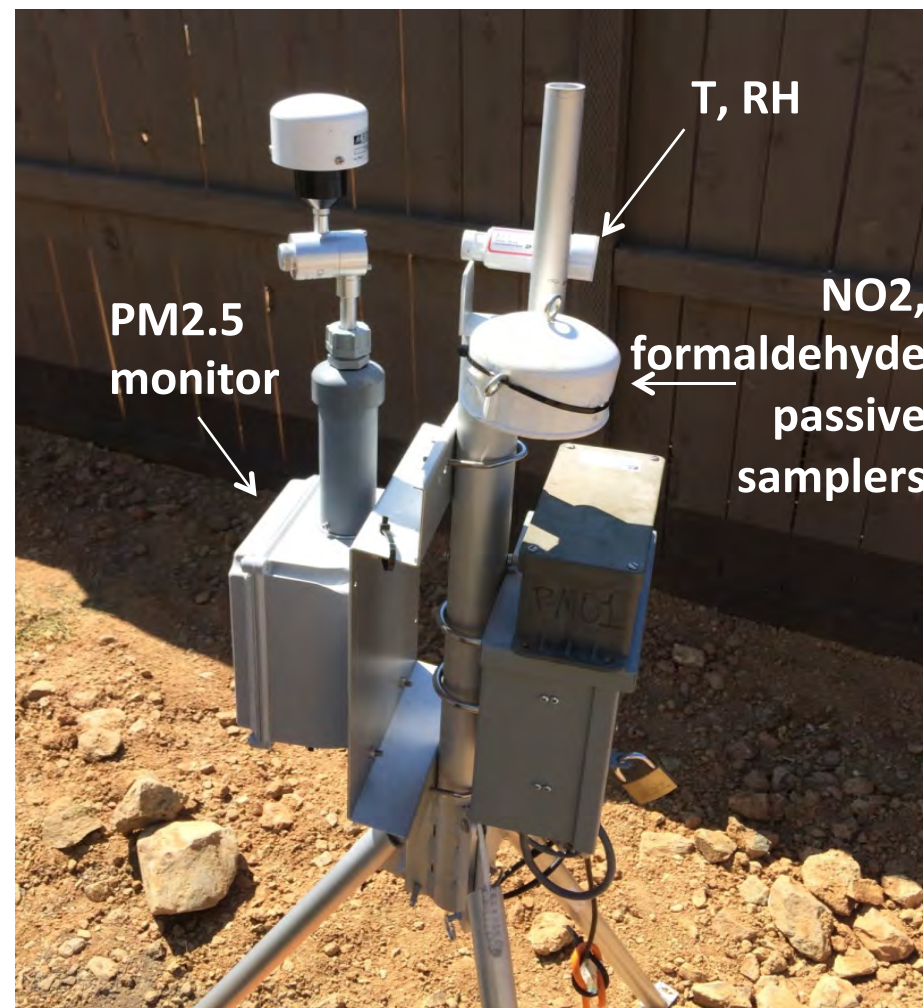
NO₂



Formaldehyde



Concurrent Outdoor Monitoring



Diagnostic Testing

Envelope and Duct Leakage



Exhaust Fan Airflow



Range Hood Airflow

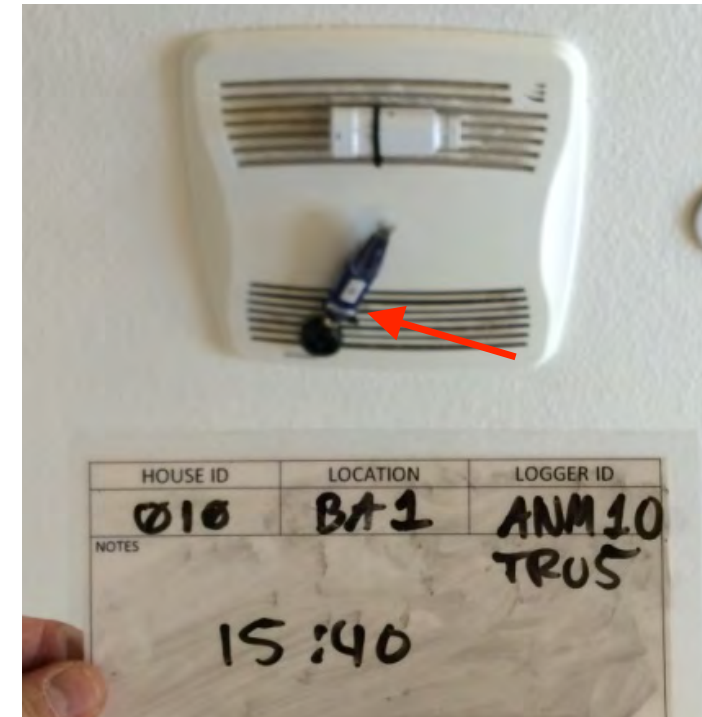


Activity Monitoring



Range hood use

Cooking (cooktop, oven)



Exhaust fan use

Activity Monitoring

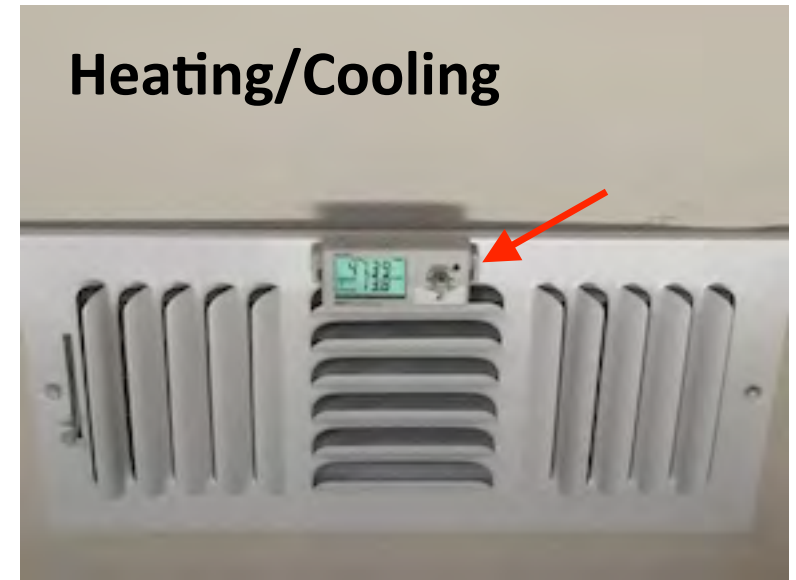
External door use (patio, garage)



Clothes dryer



Heating/Cooling



Occupant Survey and Activity Log

B. Air Quality In and Around Your Home

7. To what extent are you satisfied or dissatisfied with the indoor air quality in your home?

Very Dissatisfied									Neutral							Very Satisfied
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

8. How would you rate the outdoor air quality near where you live?

Very Poor									Neutral						Excellent
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9. How would you rate your home in protecting you from outdoor air pollution?

Very Ineffective									Neutral						Very Effective
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

C. Comfort Level in Your Home

10. In winter, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times in a month	Few times a week	Every day
Too hot in some room(s).	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Too cold in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

11. In summer, how often is the temperature in your home uncomfortable to any occupants because some room(s) are too hot or too cold?

	Never	Few times a year	Few times in a month	Few times a week	Every day
Too hot in some room(s).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Too cold in some room(s).	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Healthy Efficient New California Homes Study Occupancy and Indoor Activities Data Log

Instructions: Please fill out this data log each day, or on the following day.

Please enter your estimates. If you are unsure vide your best guess.
Do not list ies of any people.

Code number for home 13

Day 1: Date 11-30-16

Date completed 11-30-16

	Midnight to 7am	7am to 11am	11am to 1pm	1pm to 5pm	5pm to 9pm	9pm to Midnight
Number of people in home	2	4	4	2	2	2
Cooktop use						
Number of minutes	0	30	0	0	.45	0
Oven use						
Number of minutes	0	0	0	0	0	0
BBQ/outdoor grill						
Number of minutes	0	0	0	0	0	0
Vacuuming						
Number of minutes	0	0	0	.25	0	0
Window Use						
Number of minutes	0	0	0	0	45min 0	0
Other notable indoor/outdoor events	3 air cleaners 24/7		carpet & floor clean			

*For example, use of fireplace, candle, air freshener, air cleaner, humidifier, unusual outdoor air quality (wood smoke, wildfire), and so on.

Whole-House Mechanical Ventilation

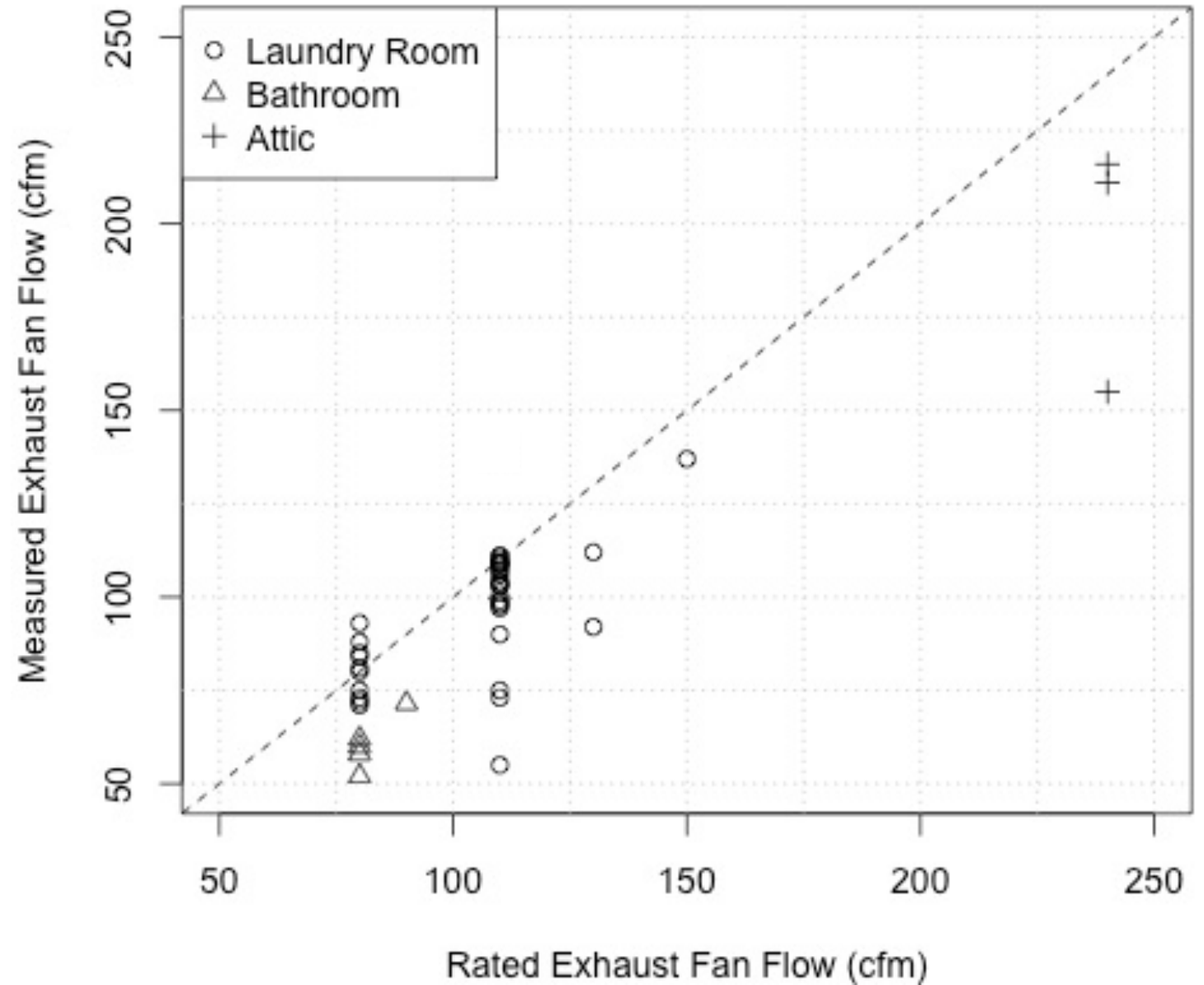
In all but 2 homes, the measured airflow of the exhaust fan exceeded the minimum requirements

On average 50% higher than minimum requirement

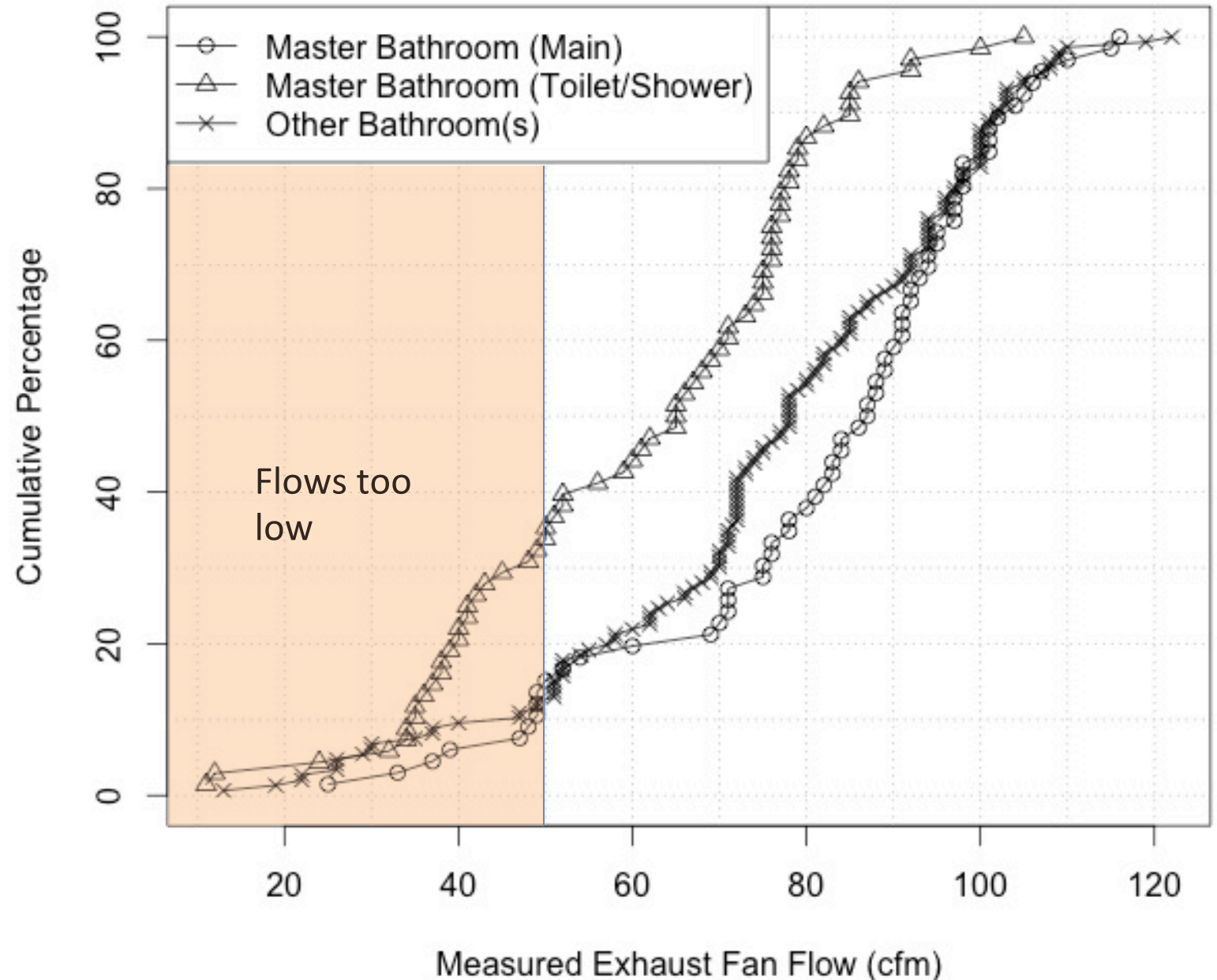
- Continuous exhaust (N=55)
- Intermittent exhaust (N=9)
- Continuous inline fan connected to central forced air system (N=4)
- Supply ventilation provided by central fan integrated system with a motorized damper (N=2)

Rated air
flows rarely
achieved

The only way to know a fan's flow: MEASURE IT

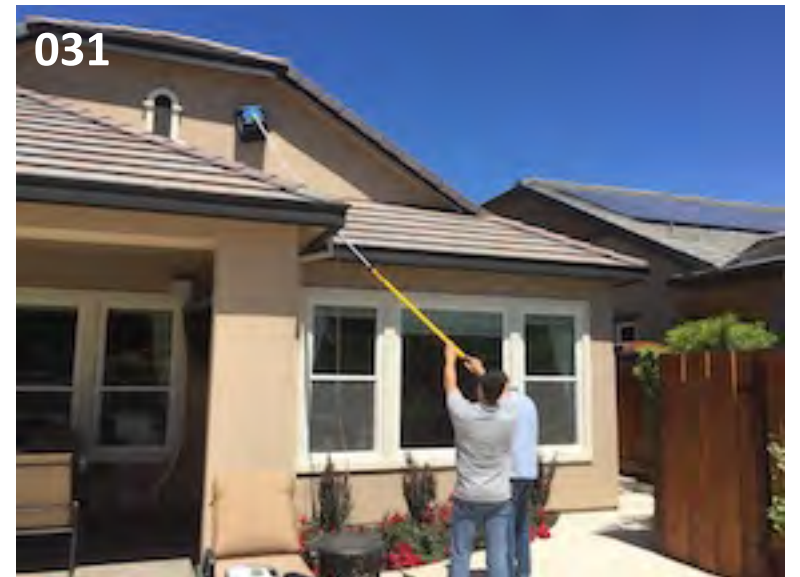


Bathroom
exhaust fans
mostly
meeting 50
cfm airflow
requirement





Supply
Ventilation
very hard
to verify



Only **1 in 4** homes with whole-house ventilation system running as found.

Whole-House Ventilation Control	Controller Labelled?	% On As-Found
On/Off Switch	No (N=42)	5%
	Yes (N=12)	58%
Programmable Controller	No (N=10)	50%
Thermostat	No (N=2)	0%
Breaker Panel	No (N=1)	100%
No Controller	No (N=3)	100%

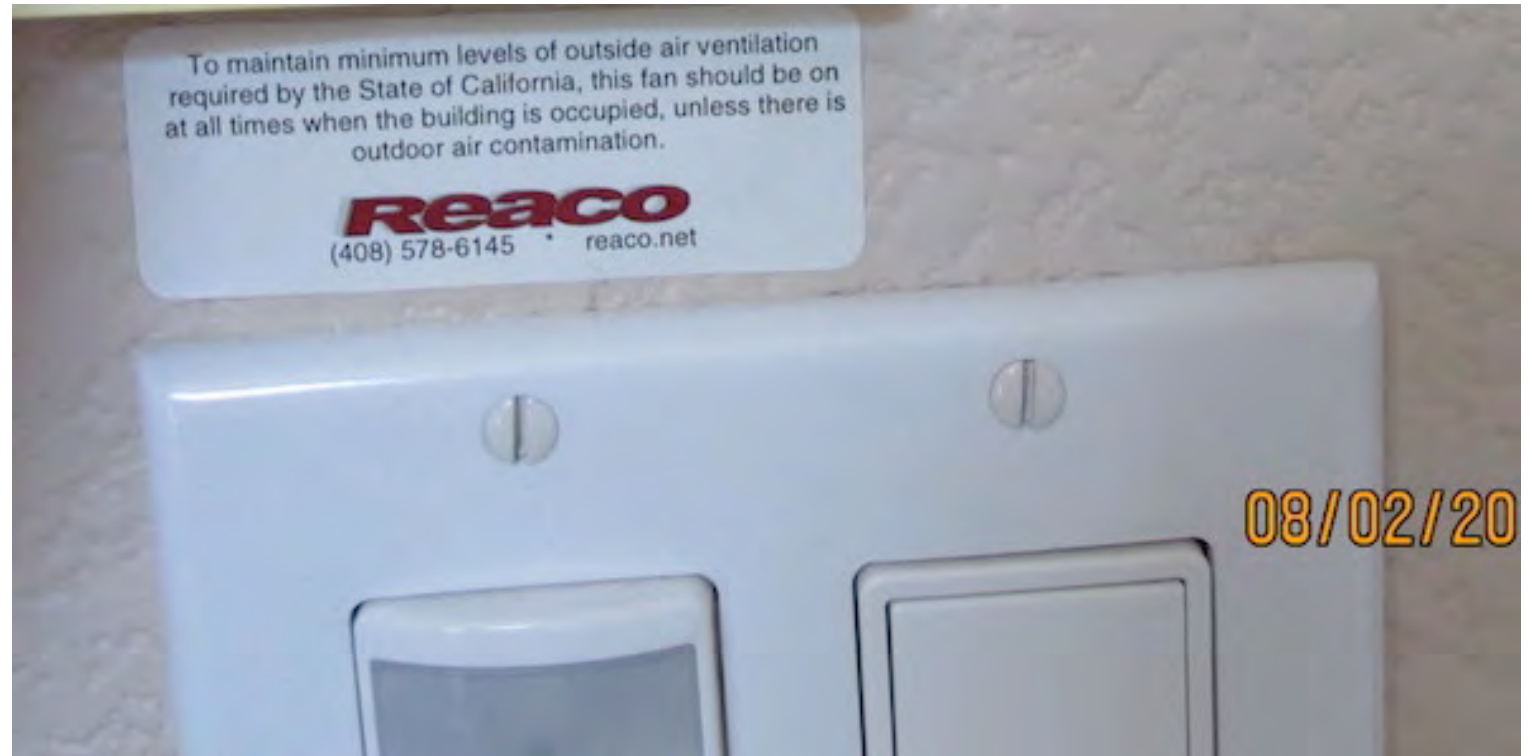


Labels not always clear

✗ CONTINUOUS DUTY



✓ To maintain minimum levels of outside air ventilation required by the State of California, this fan should be on at all times when the building is occupied, unless there is outdoor air contamination.



ASHRAE Guideline 24:

Manual switches associated with a whole-building ventilation system should have a clear label such as,

“This controls the ventilation system of the home. Leave on except for severe outdoor contamination.”

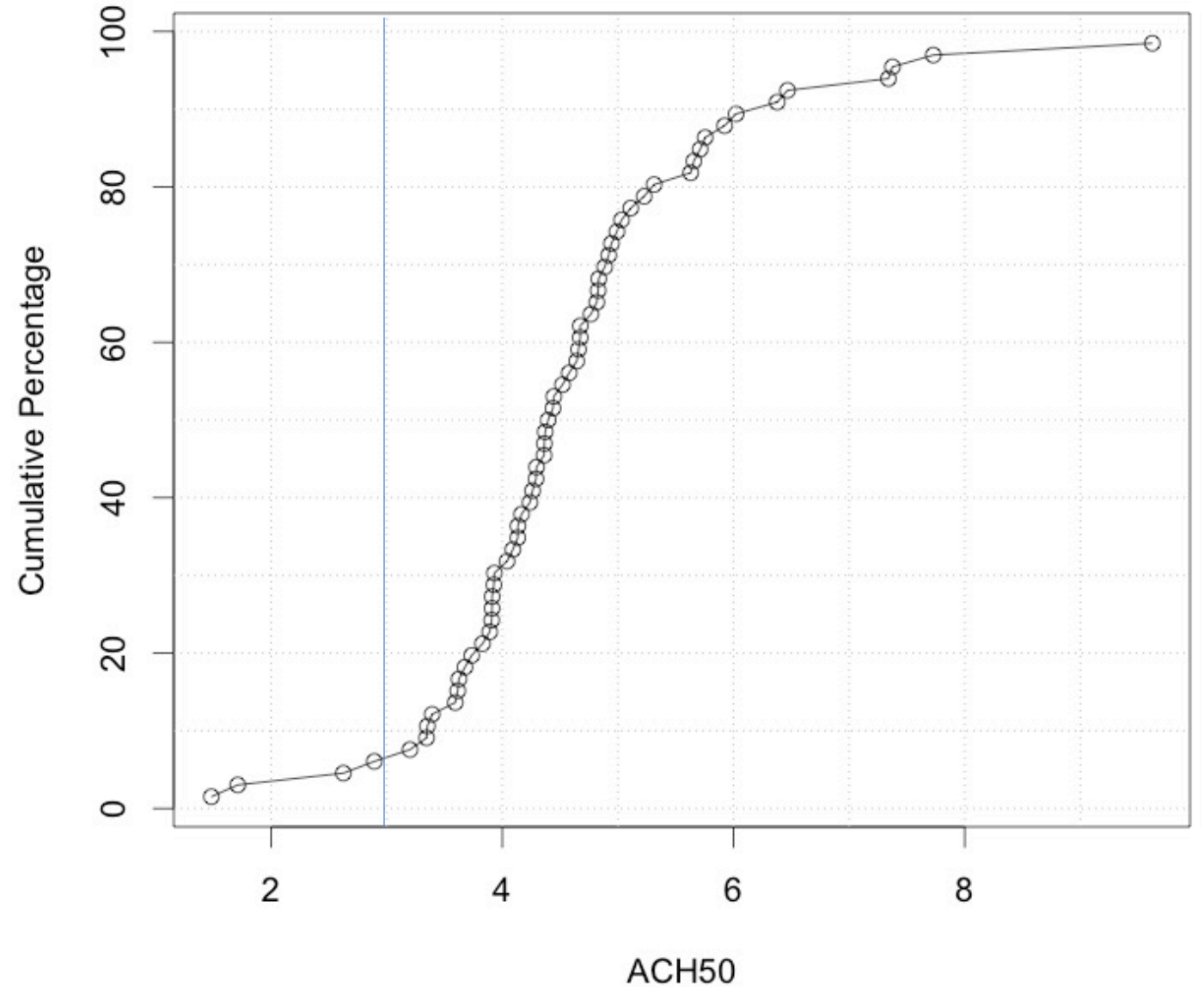
In addition, guidance on operations and maintenance procedures should be provided to occupants.

Paul Raymer:

*Label the breaker as “**TV and Ventilation**”*

Envelope Leakage

- Most homes between 3 and 6 ACH50
- Only 4 out of 70 homes <3 ACH50, IECC 2018 requirement

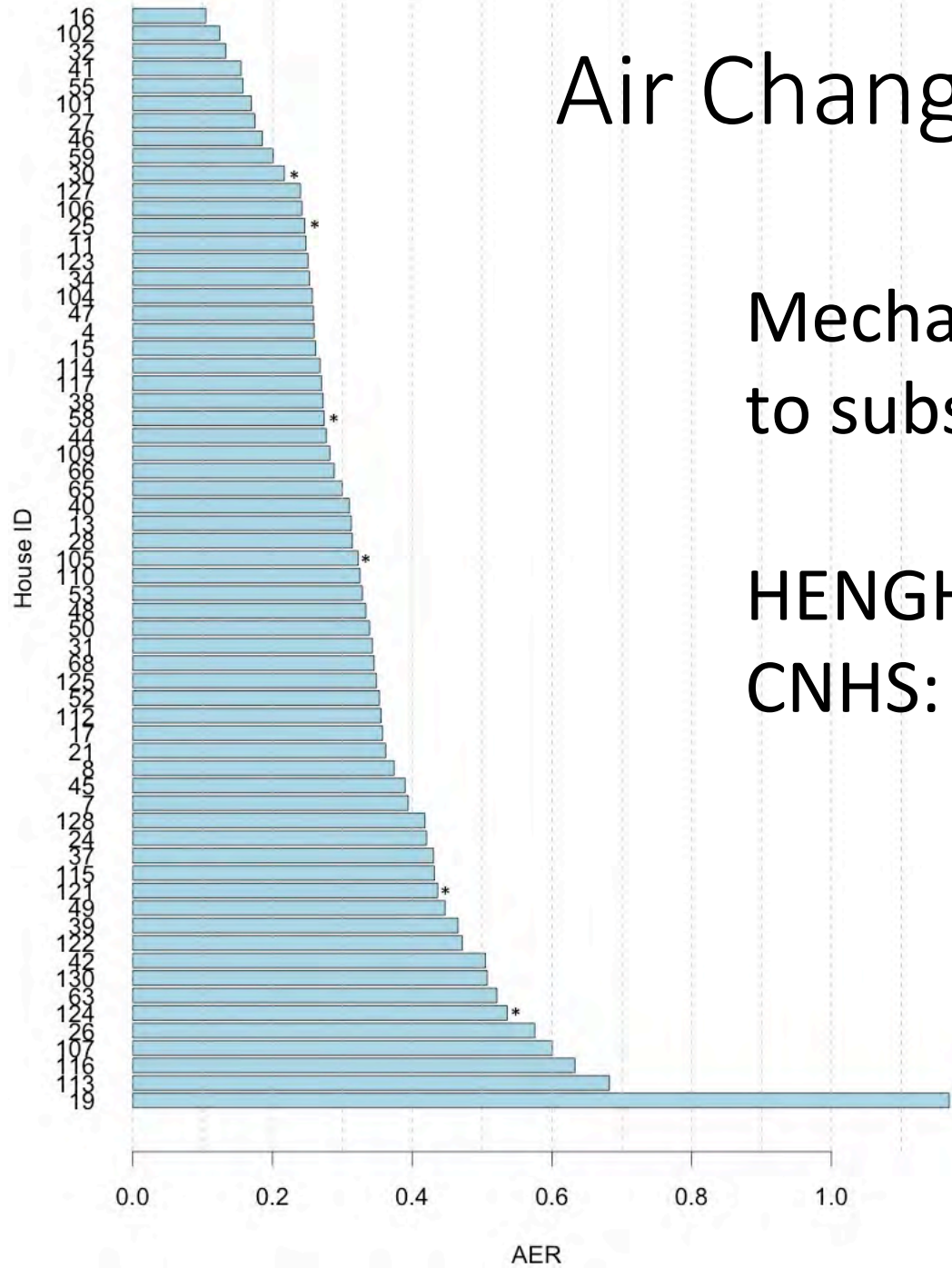


Air Change Rates

Mechanical Ventilation Requirements lead to substantially higher air change rates:

HENGH: 0.35 ACH

CNHS: 0.25 ACH

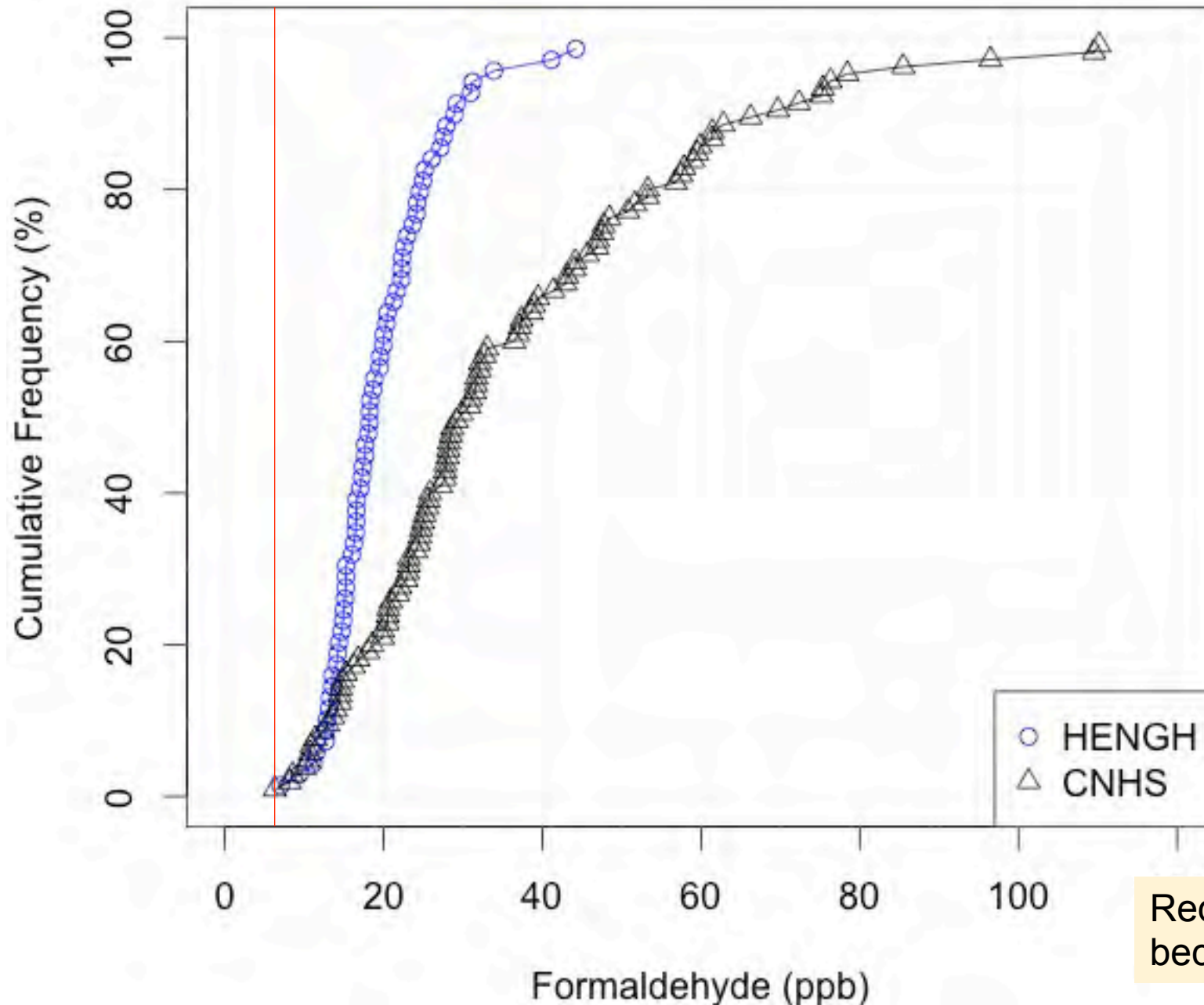


Indoor Air Quality Results

Comparisons of formaldehyde, PM_{2.5}, and NO₂ with a prior study of new homes in California suggest that contaminant levels are lower than measured from about 10 years ago.

Mean Indoor Concentration	HENGH	California New Home Study (Offermann 2009)
Formaldehyde	19.8 ppb	36.3 ppb
PM _{2.5}	8.3 mg/m ³	13.3 mg/m ³
NO ₂	6.1 ppb	5.4 ppb

OEHHA Reference Exposure Level, Chronic (7 ppb)



Formaldehyde

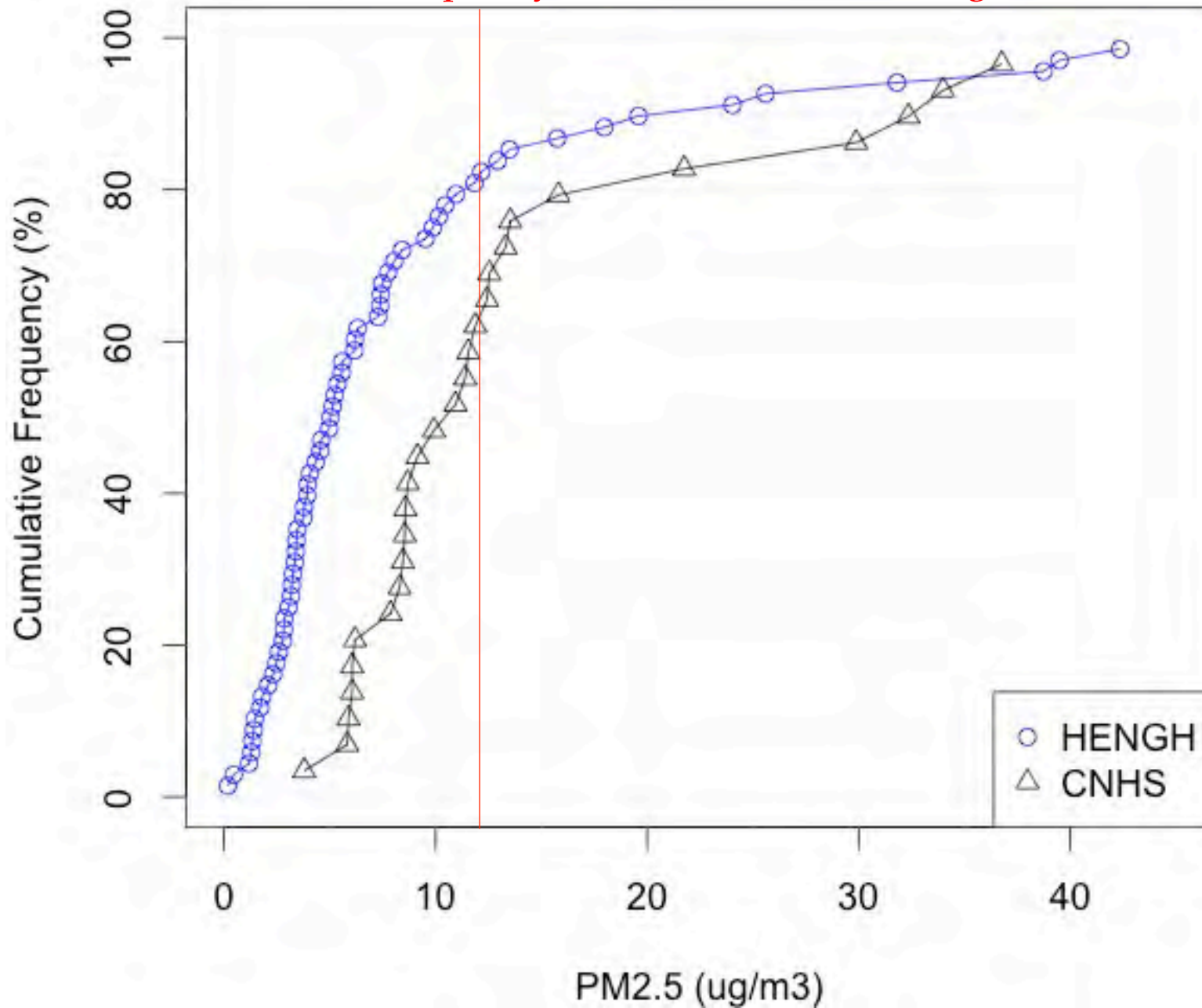
Better Ventilation
+
Lower Emissions



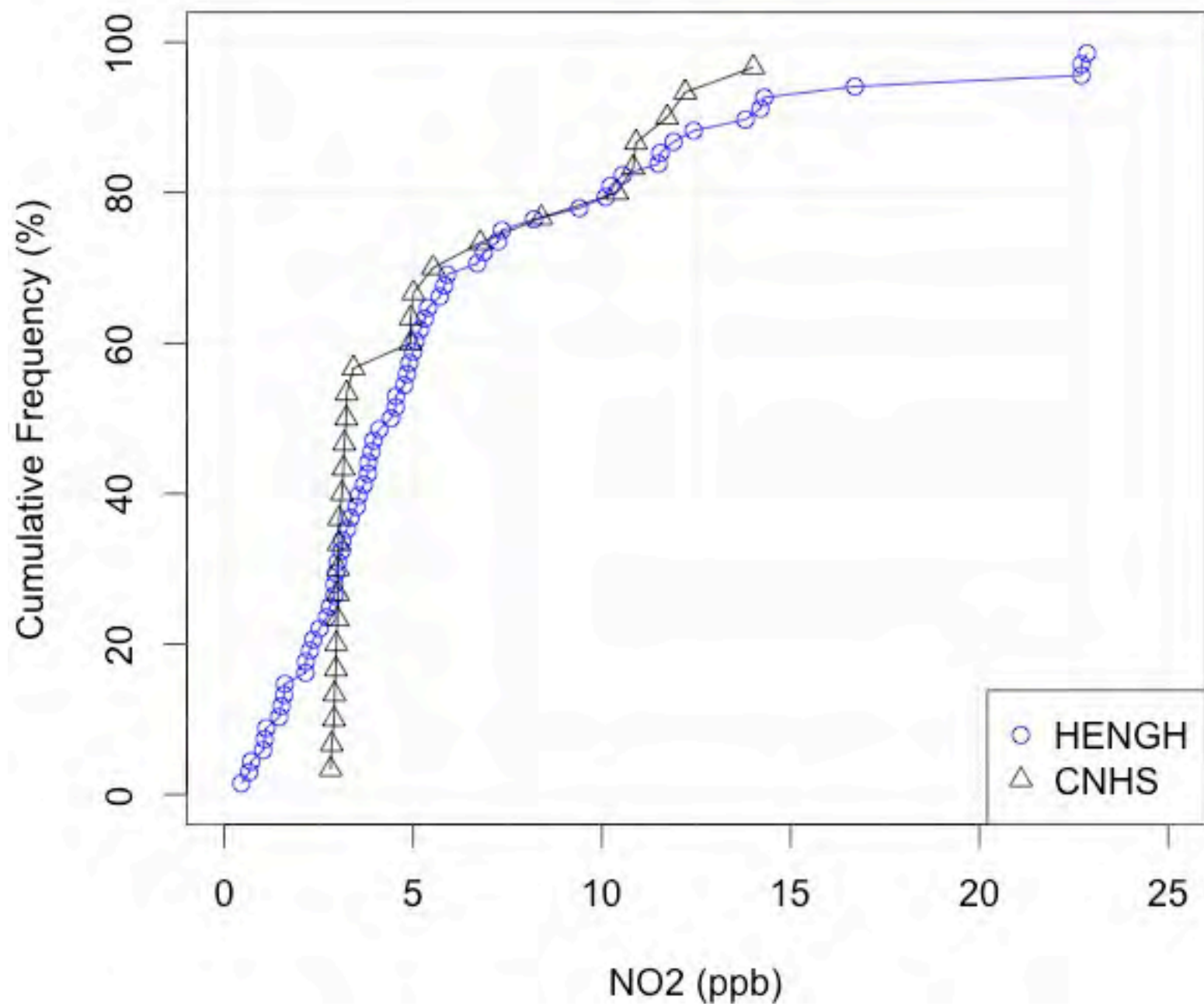
Reduced emissions composite wood products became effective January 1, 2009.

PM2.5

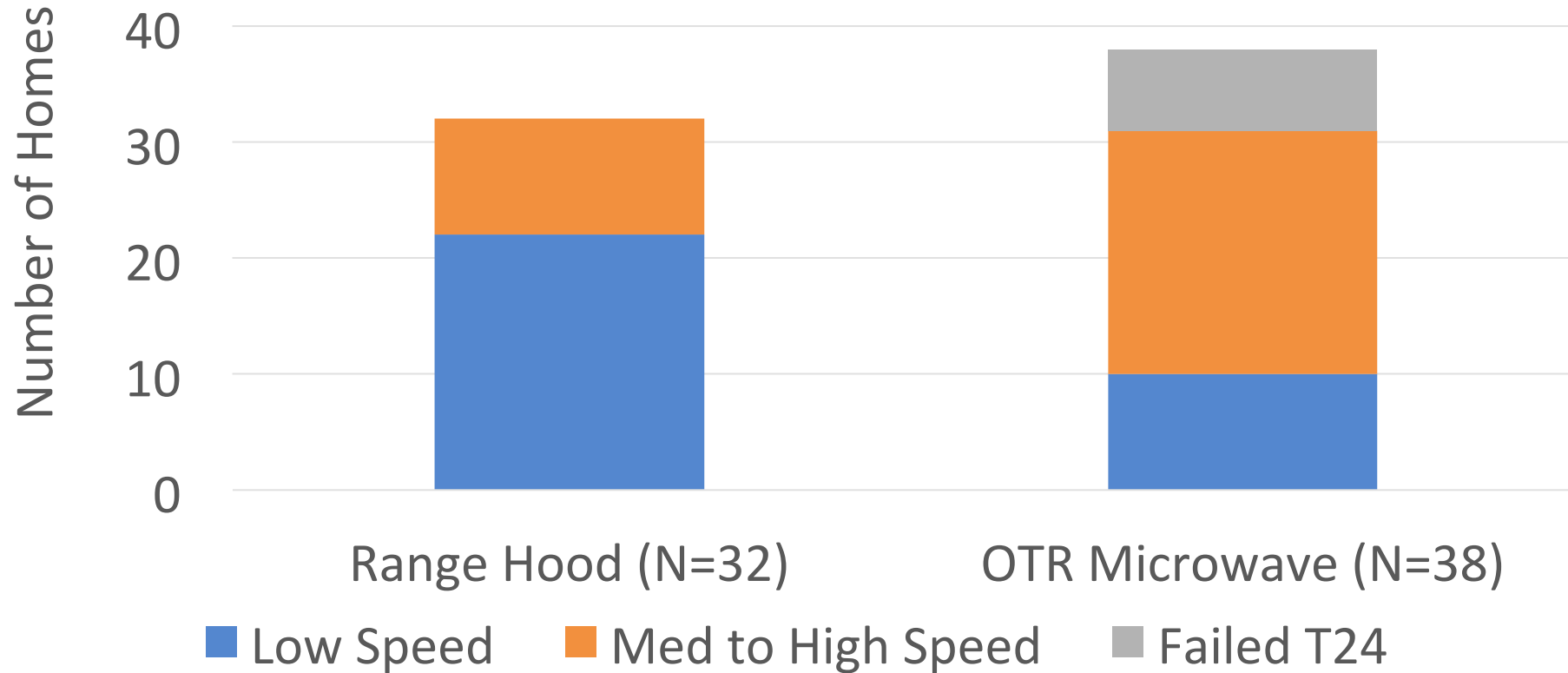
CalePA ambient air quality annual standard = 12 ug/m^3



NO₂



All kitchen range hood exhaust to outside,
most met Title 24 (100 cfm)



Particle Filtration

- Exhaust ventilation in homes with reasonably tight building envelope
- Medium to high efficiency air filters

MERV Rating	Number of Air Filters (N=112)
6 - 7	4
8	57
10	18
11	22
12	1
13	9
14	1

Conclusions

1. IAQ is acceptable in homes meeting California requirements
2. Better labeling would have a big impact
3. Encourage the use of commissionable systems
4. OTR microwaves are problematic
5. An airtightness requirement would not result in energy savings (so long as we require minimum ventilation)

Next steps...

Smart Ventilation for Advanced California Homes (SVACH.lbl.gov)

- Reduce energy consumption while maintaining or improving IAQ
- Control strategies to:
 - Time shift to lower energy cost
 - Time shift to avoid utility peak
 - Account for other fans
 - Account for air cleaning
 - Avoid outdoor contaminants: ozone or wildfire events
 - Allow for zonal control
 - Use low-cost sensors
- New Metrics: e.g., how to combine health, odor & moisture?
- US DOE and Aereco co-funding



Building America IAQ New Home Study

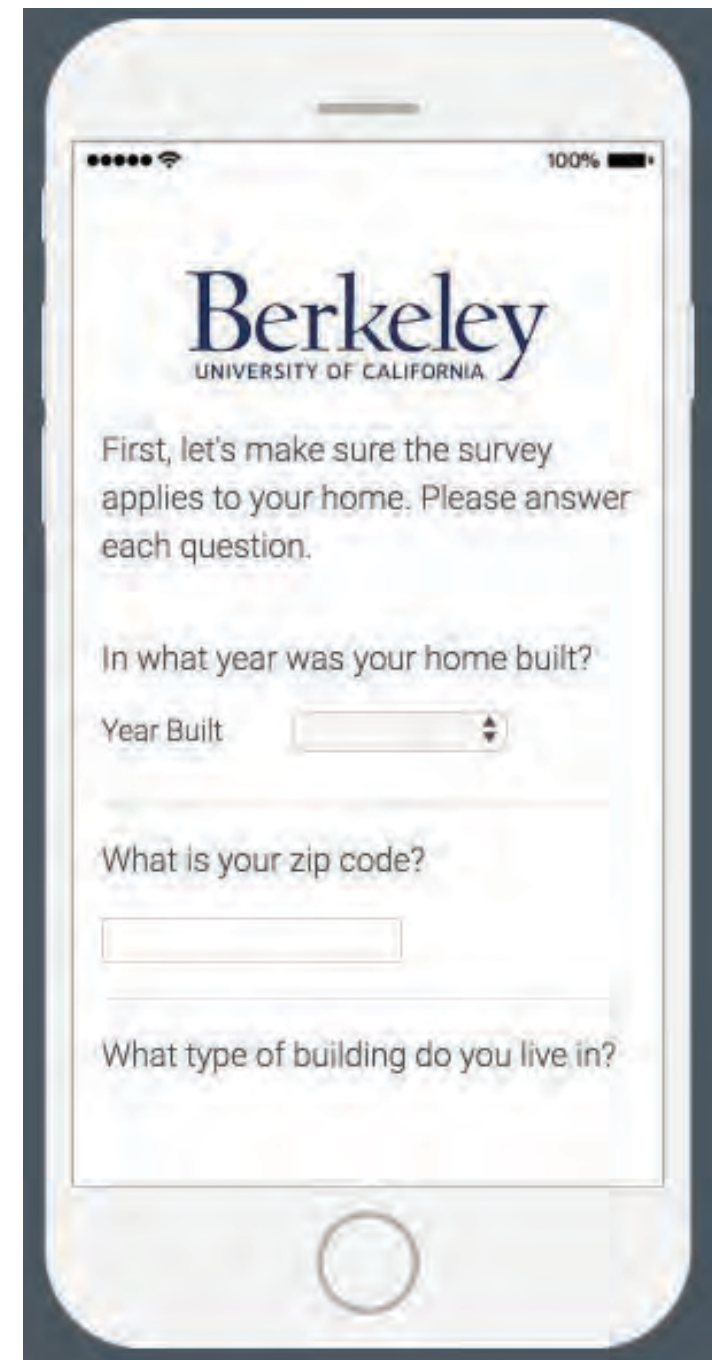
- Collect IAQ data in 32 homes each in four climate zones
 - Portland, OR
 - Boulder/Denver, CO
 - Southeast: FL, AL, GA, NC, SC
- Regional variations in system designs, performance, and occupant behaviors



Berkeley Lab Indoor Air Quality Survey

Our goal is to learn how people like you *feel* about your home environment and about the factors that can affect your indoor air quality, or "IAQ".

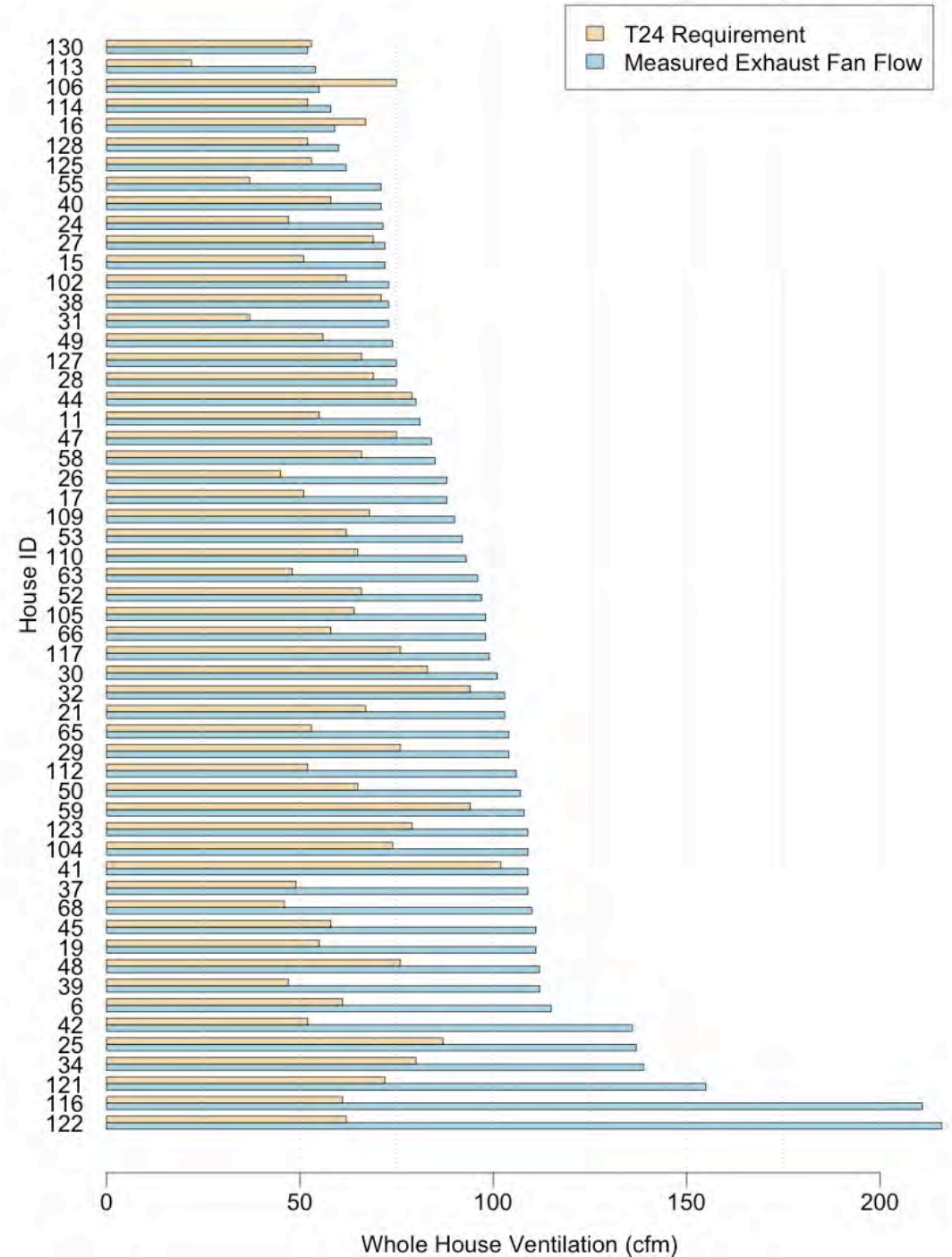
The survey asks about your satisfaction, perceptions, activities and product use. There are also questions about your home and household.



The image shows a smartphone screen with the Berkeley Lab Indoor Air Quality Survey app. The screen displays the Berkeley University of California logo at the top. Below the logo, there is a message: "First, let's make sure the survey applies to your home. Please answer each question." The first question is "In what year was your home built?" with a "Year Built" label and a dropdown menu. The second question is "What is your zip code?" with a text input field. The third question is "What type of building do you live in?" with a text input field. The phone's status bar at the top shows signal strength, Wi-Fi, and 100% battery.

Questions?

Comparison of measured exhaust fan flow and Title 24 mechanical ventilation requirement (N=56)



Problems Affecting Occupant Comfort a Few Times per Week or More Frequently	Field Study (N=70)	HENGH Survey (N=2271)
Too hot in summer	31%	41%
Too cold in winter	29%	20%
Not enough air movement	21%	18%
Too hot in winter	14%	10%
Indoor air too dry	9%	11%
Too cold in summer	4%	9%
Too much air movement	1%	5%
Musty odor	1%	3%
Indoor air too damp	1%	2%

Supply Ventilation Air Filter





Duct Leakage

Duct Leakage (DeltaQ*)	% of 70 Homes
<50 CFM	25%
50–100 CFM	30%
100–200 CFM	31%
>200 CFM	14%

*DeltaQ test measures duct leakage at working pressure, not at 25 Pa.

Data from HERS registry (CF-6R)

21 of 23 homes reported duct leakage measured at 25 Pa ranging between 50 and 100 CFM.